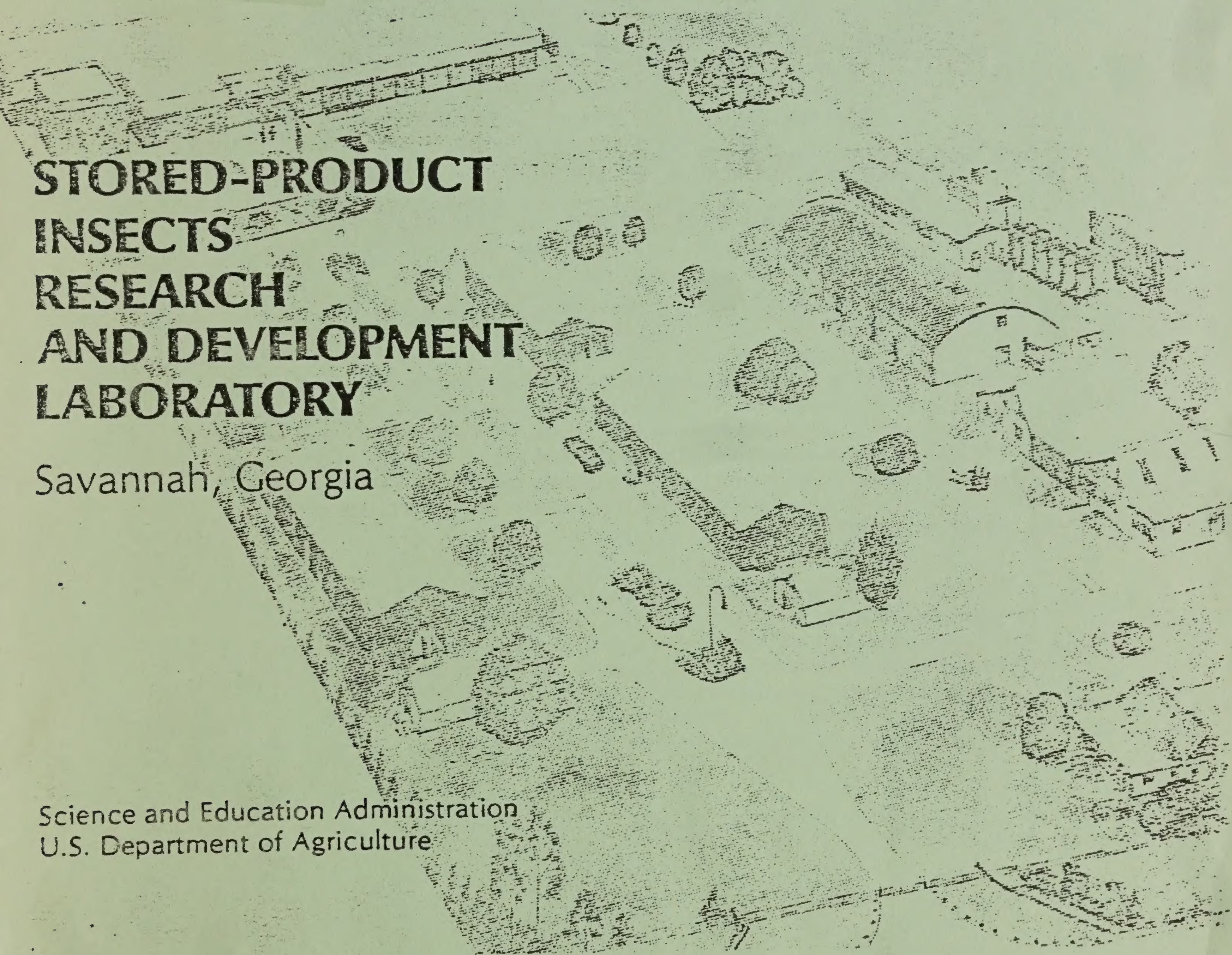
1981 Status Report of Stored-Product Insects Research of Military Importance



Presented at
Armed Forces Pest Management Board Meeting
Gainesville, Florida
March 2-6, 1981

STORED-PRODUCT INSECTS RESEARCH AND DEVELOPMENT LABORATORY

Dr. Robert Davis, *Supervisory Research Entomologist*
Laboratory Director

The Stored-Product Insects Research and Development Laboratory is an integral part of the USDA Science and Education Administration's market quality research program. The Laboratory's mission is to conduct research on the development of new and improved methods of controlling insects and preventing their damage in stored products—food, feed, seed, and fiber in the marketing channels. These channels extend from harvest through all storing, processing, and transporting phases until the commodity or product is consumed.

To fulfill the Laboratory's mission, the research and development program is spread among five research units for operational purposes. These research units are: the Biological Research Unit, the Chemical Control Research Unit, the Environmental and Special Problems Research Unit, the Pesticide Residue Analysis Research Unit, and the Physical Control Research Unit.

FORWARD

We believe that this report covers all of the research of military interest conducted at the Stored-Product Insects Research and Development Laboratory. It includes research supported with funds from the U. S. Department of Agriculture's appropriations equivalent to those formerly designated as "military funds," research conducted with additional funds from the U.S. Department of Agriculture's appropriations, and research supported directly with financial aid from the U.S. Army Natick Research and Development Command.

When you have completed your perusal of this report, I am sure you will agree with us that 1980 has been a productive year. From the standpoint of productivity we did not meet many of the goals set for ourselves. In many instances these goals were too high but they were established to give us objectives to strive for. The list of publications at the end of this report and the potential impact of many of the projects reported will confirm that our year was a success.

The most striking change in this status report from that of last year's is not in the scientific results report, but rather in the organizational changes at the laboratory. It will be noted that there are now three research units instead of five as shown in our last report. This restructuring has provided far better communication among scientists of similar interests and hopefully will improve opportunities for team research. It also has reduced the administrative work load on several scientists and should provide more opportunities for productive research.

As you go over the personnel list, you will also note that we have added two research entomologists to our staff. One is Mr. L. D. Cline, a promotion, and the other is Dr. D. W. Keever, a new employee. Dr. Keever is filling the vacancy created by the retirement of Dr. G. L. LeCato.

We would like to express our appreciation to personnel of the U.S. Army Natick Research and Development Command, the entomological staff at the Defense Personnel Support Center, and personnel at the Jacksonville Naval Air Station for support in the areas of physical facilities and finances.

1981 Status Report of Stored-Product Insects Research of Military Importance

INDEX

Stored-Product Insects Research and Development Laboratory
3401 Edwin Street (P. O. Box 22909)
Savannah, Georgia 31403

Dr. Robert Davis, Laboratory Director
A. Elaine Durden, Secretary

Administrative Office

Jack C. Ellis, Administrative Officer
Charles E. Metts, Purchasing Agent
Christina Christy, Accounts Maintenance Clerk
Annette D. Moylan, Personnel Clerk (Typing)

Clerical Section

P. Les Carter, Jr., Clerk-Typist
Sarah E. Grubbs, Clerk-Stenographer
Charlene Freyermuth, Library Technician
Vacancy, Clerk-Typist

Maintenance Section

Kenneth A. Purvis, Air Conditioning Mechanic
Donald J. Agnew, Machinist
Leroy R. Wilson, Carpenter
Ed W. Palmer, Motor Vehicle Operator
Vacancy, Maintenance Worker
David C. Howe, Maintenance Foreman

Insect Rearing

Ronald E. Myers, Biological Technician Insects
George F. Haussmann, Insect Production Worker

Biology and Biological Control Research Unit

Dr. Richard T. Arbogast, Sup. Res. Ent., Research Leader
Dr. John H. Brower, Research Entomologist
Dr. James E. Baker, Research Entomologist
Dr. Patrick T. M. Lum, Research Entomologist
Dr. Michael A. Mullen, Research Entomologist
John W. Press, Research Entomologist
Dr. Dennis W. Keever, Research Entomologist
Richard V. Byrd, Biological Lab Technician
B. Ray Flaherty, Biological Lab Technician Insects
Stanley M. Woo, Biological Lab Technician
Margaret S. Carthon, Biological Technician Insects
Alice M. Miller, Biological Lab Technician
J. Linda Robertson, Biological Lab Technician
Vacancy, Biological Lab Technician

Chemical Control Research Unit

Hagan B. Gillenwater, Sup. Res. Ent., Research Leader
- E. Wayne Tilton, Research Entomologist
- L. M. Redlinger, Research Entomologist
- Dr. R. A. Simonaitis, Research Chemist
- Dr. J. Larry Zettler, Research Entomologist
- Robert L. Kirkpatrick, Research Entomologist
- Dr. James G. Leesch, Research Entomologist
- Dr. James M. Zehner, Research Chemist
- Henry H. Vardell, Research Entomologist
- Robert S. Cail, Physical Science Technician
- Gerald Eason, Biological Technician
- Lehman L. McDonald, Biological Lab Technician
- Dennis R. Sukkestad, Biological Technician
- Ezekiel Cooper, Physical Science Technician
- Morris Cooper, Physical Science Technician
- Ruby D. Jones, Biological Lab Technician
- Edith H. Doyle, Physical Science Technician
- Vacancy, Biological Technician Insects
- Vacancy, Biological Technician Insects
- Vacancy, Biological Technician
- Vacancy, Biological Technician

Environmental and Special Problems Research Unit

Roy E. Bry, Res. Ent., Research Leader
- Dr. Henry A. Highland, Research Entomologist
- Dr. William A. Bruce, Research Entomologist
- Dr. Edward G. Jay, Research Entomologist
- Dr. Helen C. F. Su, Research Chemist
- Larry D. Cline, Research Entomologist
- Vacancy, Agricultural Engineer
- Joe H. Lang, Biological Technician Insects
- Gordon C. Pearman, Biological Technician Insects
- Gwendolyn L. Anderson, Physical Science Technician
- Ronald E. Boatright, Biological Lab Technician
- Jeanette M. Collins, Biological Lab Technician
- Vacancy, Biological Technician Insects
- Vacancy, Physical Science Technician

BIOLOGICAL INVESTIGATIONS

IDENTIFICATION OF THE EGGS OF STORED-PRODUCT INSECTS

Investigator

R. T. Arbogast

The usefulness of the scanning electron microscope as an analytical tool for identification of insect eggs was pointed out in the last annual report. Useful diagnostic characters for identifying eggs of stored-product moths were described, and a key to ten important species was presented.

We have now completed study of the eggs of the meal moth, *Pyralis farinalis* (L.), and the murky meal moth, *Aglossa caprealis* (Hübner), and a manuscript describing them has been prepared for publication. These species have been incorporated into the diagnostic key as follows:

KEY TO THE EGGS OF SOME SPECIES OF STORED-PRODUCT MOTHS

1. Fusiform, anterior end truncate, reticulation consisting of prominent longitudinal ridges joined by lesser cross ridges........*Sitotroga cerealella* (Olivier)

   Various shapes, anterior end never truncate, reticulation consisting of various patterns of polygons or sinuous ridges....................2

2. Reticulation comprised of intersecting sinuous ridges................6

   Reticulation comprised of irregular polygons.........................3

3. Subcylindrical, primary cells oval to nearly circular, aeropylar openings unguarded.................*Tineola bisselliella* (Hummel)

   Spheroid, ellipsoid, ovoid, or obovoid, primary cells wedge-shaped with rounded outer margins, aeropylar openings surrounded by distinct collars...4

4. Reticulation at least faintly visible over entire surface, carinae surrounding primary cells of uniform width..........................5

   Reticulation limited to anterior end, carinae surrounding primary cells conspicuously broader around outer margins of cells....... ....*Achroia grisella* (F.)

5. Cell discs densely marked by minute pits, carinae following a zigzag path between intersections.....*Aglossa caprealis* (Hübner)

   Cell discs wrinkled, lacking pits, carinae following a more or less direct path between intersections.......*Galleria mellonella* (L.)

6. Cell discs roughened by numerous small excrescences, at least some carinal segments on ridges near equator..............................7

   Cell discs smooth, although often with numerous small particles scattered over their surface, carinae restricted to the micropylar area or at least absent from ridges near the equator................9

7. Primary cells subequal, ridges with carinae that are more or less continuous over the entire surface, excrescences of cell discs rounded...8

   Primary cells unequal, some much larger than others and overlapping the outer ends of adjacent cells, excrescences of cell discs sharp edged.................................Anagasta kuehniella (Zeller)

8. Outer ends of most primary cells straight or angular, aeropylar openings always surrounded by a broad, single collar.......... ....Plodia interpunctella (Hübner)

   Outer ends of primary cells rounded, aeropylar openings normally surrounded by a double collar............Pyralis farinalis (L.)

9. Prominent tubercles present at most ridge intersections, carinae restricted to micropylar area..................................10

   Prominent tubercles absent, carinae extending well beyond micropylar area on anterior end, short carinal segments present on posterior end............................Corcyra cephalonica (Stainton)

10. Ridges closely spaced, cell discs restricted.......................11

    Ridges widely spaced, cell discs broad..Cadra figulilella (Gregson)

11. Aeropylar openings surrounded by distinct collars.................. ....Ephestia elutella (Hübner)

    Aeropylar openings unguarded.............Ephestia cautella (Walker)

Beetle eggs have proved more difficult to study because they collapse during sputter coating or in the column of the scanning electron microscope. We are now experimenting with freeze drying or fixation with osmium as a means of overcoming this difficulty.

Future Plans

Plans are now being made to study the eggs of the brown house moth, Hofmannophila pseudospretella (Stainton), and the whiteshouldered house moth, Endrosis sarcitrella (L.). Other species will be studied as they become available. Study of stored-product beetle eggs will proceed as soon as we perfect a technique for preserving their structure during sputter coating and in the microscope.

EFFECTS OF LOW TEMPERATURES ON STORED-PRODUCT INSECTS

Investigators:

M. A. Mullen and R. T. Arbogast

As part of a study on limiting factors influencing the population dynamics of stored-product insects, the effects of exposure to low temperatures is being investigated. Larvae, pupae, and adults of 10 species of stored product insects are being exposed to -10°, -5°, 0°, +5°, and +10°C for varying periods of time. The LT50 and LT95 for each species and stage at each temperature is being calculated. The LT95 at -10°C for each stage and species is given in Table 1. With the exception of the pupae of the sawtoothed and merchant grain beetles, the larval stage is more resistant than any other stage. The cold resistance of the larvae is probably due to its ability to supercool which allows it to survive long exposures to subfreezing temperatures.

Information on the effects of exposure to low temperatures may be useful to the military to disinfest stored subsistance items.

Future Plans

The required exposure periods will be completed at -10°C and will be expanded to include -5°, 0°, +5°, and +10°C.

Table 1. LT95 (hours) for each stage of 10 species of stored-product insects exposed to -10°C.

Insect	Stage			
	Young Larvae	Old Larvae	Pupae	Adult
Drugstore Beetle	18.2	10.2	NC*	10.1
Cigarette Beetle	9.4	33.9	7.3	9.6
Red Flour Beetle	6.6	18.4	NC*	5.6
Confused Flour Beetle	10.4	8.3	NC*	3.3
Sawtoothed Grain Beetle	1.74	2.7	19.4	3.2
Merchant Grain Beetle	2.8	2.0	30.8	NC*
Indian Meal Moth	NC*	21.8	2.3	NC*
Almond Moth	3.0	7.8	1.8	1.2
Rice Moth	1.2	3.3	NC*	NC*
Mediteranian Flour Moth	2.3	NC*	NC*	NC*

*NC - not completed at time of report

STUDIES ON THE PROCESSES OF DIGESTION IN KERATINACEOUS INSECTS

Investigator

J. E. Baker

This research provides basic biological data to supplement the mothproofing program at the SPIR&DL. Insight into the enzymatic mechanisms of protein digestion in these species may provide means of alternate control procedures.

There are 3 main trypsin-like enzymes in midguts of larvae of the black carpet beetle, *Attagenus megatoma*. The two cationic trypsins were designated CT-1 and CT-2 and there was a single anionic trypsin, AT. These 3 enzymes were purified and their cleavage specificities were determined and compared to that of bovine trypsin. Each enzyme was incubated with the polypeptides glucagon or oxidized ribonuclease A and the digestion products were analyzed. Although the cleavage specificities of the insect trypsins were similar to that of bovine trypsin, differences in peptide bond specificities were noted between CT-1, CT-2, and AT, and also between each of the 3 insect trypsins and the bovine enzyme. These differences in specificity apparently indicate a complementary role in the digestion of dietary protein by the multiple trypsins in this insect.

Several properties of the aminopeptidase isolated from this species were studied. The enzyme is apparently a metalloprotein since it was inhibited by the metal chelators EDTA and 1,10-phenanthroline and cations, such as Co^{++}, Mn^{++}, and Zn^{++} would activate dialized preparations. The enzyme hydrolyzed L-amino acids from the *N*-terminal end of di- and tripeptides. Peptides with terminal L-leucine were preferred substrates. Kinetic constants were obtained for the hydrolysis of 10 amino-acyl-β-napthylamides. The enzyme had the highest affinity for leucyl-β-NA (Km 0.03 mμ) and the lowest affinity for prolyl-β-NA (Km 2.78 mμ).

The cationic carboxypeptidase was purified through a sequence of chromatographic steps that included a SBTI- affinity gel column. Two fractions were isolated: CMS-G-1 and CMS-G-2. CMS-G-2 was quite specific for carboxypeptidase A substrates, such as HPLA and blocked dipeptides with carboxyl terminal aromatic amino acids. CMS-G-1 contained about 3.5X as much total protein as CMS-G-2 and was more general in its peptide specificities. Z-valyl-leucine and Z-glycyl-methionine were the most sensitive substrates for CMS-G-1. Both the terminal and penultimate amino acids in the dipeptides influenced the peptidase activity. The peptidases had MW's of about 35,500, were most active between pH 7.5 to 8.5, and were inhibited by metal chelators and heavy metals.

The distribution of the aminopeptidase and carboxypeptidase within the midgut differed somewhat from that of the trypsins and chymotrypsins. All of the endopeptidase activity (98%) was found in the midgut lumen contents. However, significant levels of aminopeptidase activity (6%)

and carboxypeptidase activity (33%) were associated with the midgut epithelium. These latter studies indicated that a spatial distribution of digestive proteinases may exist within the gut of _A. megatoma_ and that the terminal stages of digestion may occur on or within the epithelial layer.

Future Plans

Attempts will be made to use isoelectric focusing procedures to separate all of the digestive enzymes in a single analytical step. The technique will then be used to study the relative rate of synthesis of individual enzymes in response to diet.

PARASITIC AND PREDATORY MITES FOR INSECT CONTROL

Investigator

W. A. Bruce

The mite, *Pyemotes tritici*, has been shown, in laboratory and limited field studies, to have potential as a biological control agent of stored-product insects as well as other pests such as the red imported fire ant. Efforts have been directed toward rearing the mite on an artificially defined diet to facilitate the establishment of a mass rearing program. To date, two objectives have been achieved: (1) *P. tritici* has been induced to feed through an artificial membrane and, (2) an artificial diet has been developed that will promote growth and reproduction similar to the natural host.

Future Plans

Research will continue to refine the artificial diet and to develop the microencapsulation techniques necessary to enhance the rearing program.

PROTECTION OF SUBSISTENCE ITEMS

INVESTIGATIONS OF NEW INSECTICIDES AND REPELLENTS

Demonstration of the potential of new compounds for use as insecticides or insect repellents is important to the developmental phase of the chemical control research program for the laboratory. Subsequent to showing the potential of a quality compound for use against stored-product insects, the decision of the supplier to pursue marketing of the compound is a determining factor for initiating follow-up studies. To protect the suppliers' interests, we have been requested not to include in any report new compounds whose identity is coded until the period of confidence has expired. Therefore, only "S" numbers (Savannah numbers) will be used in parts of this report.

Investigator

L. L. McDonald

Evaluation of new compounds as repellents

Of 121 compounds evaluated as repellents against confused flour beetle adults, 39 produced repellency ratings equal to or greater than the average class III rating for the pyrethrins + piperonyl butoxide standard. Twelve of these 39 compounds, S-3407 through S-3410, S-3425, S-3426, S-3588, S-3589, S-3593 through S-3595, and S-3636, were class IV repellents and are considered promising for follow-up evaluation.

Evaluation of new compounds as insecticides

Preliminary evaluation of new compounds as insecticides included 7 as direct-contact (topical application) and 7 as residue (on paper and aluminum surfaces) toxicants. Results showed that S-3674, S-3675, and S-3689 were promising as direct contact toxicants against black carpet beetle larvae and flour beetle adults. Two of the above, S-3675 and S-3689, were also promising as a residue toxicant against both species of test insects.

Future Plans

Evaluation of new compounds as repellents and insecticides against stored-product insects will continue as the compounds are available.

EVALUATION OF NEW COMPOUNDS AS QUARANTINE-TYPE SPACE TREATMENTS

The development of safe, effective pesticides for use in quarantine treatments for both domestic and import-export purposes is of significance in maintaining our favorable trading position on world markets. Such treatments are also of vital interest to our government in allowing it to fulfill its military obligations and its humanitarian commitments such as our Food for Peace program.

Investigator

R. L. Kirkpatrick

Tests were conducted in tractor trailers located in Miami, Florida, for the evaluation of improved pesticide formulations for the quarantine treatment of aircraft, ships, and vans. Adult confused flour beetles, *Tribolium confusum* Jacquelin duVal, and black carpet beetle larvae, *Attagenus megatoma* (F.), were exposed to the following insecticides applied at the rate of 0.125 to 0.8 g. a.i./1,000 ft.3 as aerosols and 0.2 to 1.7 g. a.i. as dusts: DDT (AI3-1506) + carbaryl (AI3-23969), fenvalerate (AI3-29235), fluvalinate (AI3-29426), M-108 (AI3-29593), M-9270 (AI3-29471), M-9526 (AI3-29472), M-9580 (AI3-29473), M-9751 (AI3-29474), S-2703 Forte (AI3-29594), sumithrin (AI3-29063), U-47319 (AI3-29291) and three additional compounds still classed as confidential.

The 10% formulations of M-9270, M-9580, M-9751, and sumithrin controlled (98% or more mortality) the black carpet beetle larvae, whereas M-9270 and M-9580 gave the best control for both species of insects.

Future Plans

The evaluation of improved formulations of new pesticides applied as quarantine-type treatments with other Governmental agencies will be continued.

EVALUATION OF FUMIGANTS

Investigators

J. G. Leesch and D. R. Sukkestad

Evaluation of new compound (TD-5032) as a fumigant

The compound TD-5032 (AI3-27428) was tested in order to evaluate its ability to penetrate a large mass of grain. Wheat was placed in 55-gal. drums and adult *Tribolium confusum* and immature stages of *Sitophilus oryzae* were placed at various positions in the wheat mass from the top to the bottom. The TD-5032 was applied as a 0.5% solution in hexane just under the surface of the grain to achieve a dosage of 0.6 mg/l. based on the total volume of the drum. Periodically after fumigant application and sealing of the drums, air samples were taken at positions located vertically in the grain mass from top to bottom and analyzed by gas chromatography in order to determine the movement of the TD-5032 vapors downward. Drums remained sealed for 5 days after application. All insects in the top two-fifths of the grain mass were killed. However, in the center of the grain mass only up to 22% of the *Tribolium confusum* were killed although 99% of the *Sitophilus oryzae* were killed. In the bottom two-fifths of the grain mass *Tribolium confusum* showed variable mortality ranging from 0 to 20% while less than 50% mortality of *Sitophilus oryzae* occurred. These tests clearly showed that TD-5032, when applied to the surface, does not penetrate a large mass of wheat very well.

Future Plans

TD-5032 will be tested against moths that attack stored products. Research to determine residues of TD-5032 remaining on commodities will be conducted. Effects of vacuum and pressure on the efficacy of TD-5032 will be tested.

Investigators

J. G. Leesch and D. R. Sukkestad

Evaluation of detector tubes and associated pumps for the determination of phosphine

Three brands of detector tubes used to determine low concentrations of phosphine were tested using five pumps to draw air samples through each brand. The accuracy of the combinations was assessed statistically using analysis of variance and the Duncan/Waller t-test. Pre-analyzed phosphine concentrations of 0.3 ppm contained in Teflon(R) bags were sampled using each tube-pump combination. Results are shown in Table 2 and indicate that all but two tube-pump combinations gave readings which were below the actual concentration of phosphine sampled. Only one of

the 18 combinations tested gave readings within the least significant difference of ±8.27% of the true concentration. Half of the combinations gave results which are ±20% of the true concentrations sampled and only two combinations gave results which were within 15% of the actual concentration.

Future Plans

Tests on gas-detection tubes for phosphine have been completed until new products become available. Testing of detector tubes for other fumigants will be tested.

Investigators

J. G. Leesch and D. R. Sukkestad

The release of phosphine from a new formulation of aluminum phosphide

A new formulation of aluminum phosphide was tested to determine its release rate of phosphine. Compared to Phostoxin(R) pellets and Detia(R) Gas EX-B bags, the new formulation evolved phosphine initially at a slightly higher rate; however, the mean release rate of phosphine obtained from the new formulation was the same as for Detia bags and significantly lower than Phostoxin pellets after 72 hr. Tests were conducted in 2010-liter fumitoria.

Future Plans

The new formulation of aluminum phosphide will be tested to determine residual levels of unreacted phosphide after exposure of the material to air for various periods of time.

Investigators

J. G. Leesch, H. A. Highland, and D. R. Sukkestad

Penetration of packaging materials by phosphine

Twenty-one commercially packaged commodities were tested to determine the penetration of phosphine through the packaging material. Tests were carried out on case lots of each commodity in a stainless steel 300-liter fumitorium. Phosphine concentrations within five or more packages of each commodity were determined throughout the fumigation and aeration of the case lots using a gas chromatograph equipped with a thermionic detector. Results are shown in Table 3 and indicate that the most difficult packages to penetrate are those made up of foil laminates, polymer and/or polyethylene and was liners, in that order.

Future Plans

Several more commodity packages will be tested for penetration by phosphine. Films used in packaging will be tested in a permeation chamber using phosphine and methyl bromide.

Table 2. The results obtained by various detector tube-pump combinations when used to sample a known concentration of phosphine

Tube	Pump					
	Auer	Drager	Gastec	MSA(1)2/	MSA(3)2/	Kitagawa
Auer	79(CD)	81(C)	115(A)	22(I)	67(EF)	22(I)
Drager	72(DE)	97(B)	122(A)	43(H)	81(C)	55(G)
Gastec	57(G)	73(DE)	84(C)	66(EF)	78(CD)	63(GF)

1/ Means followed by the same letter are not significantly different (P>0.05).

2/ The MSA pump was used with variable oriface settings #1 and #3. The flow of air is more restricted at setting #1 as compared to #3.

Table 3. Concentrations of phosphine outside and inside of packaged commodities during fumigation and concentrations of phosphine inside packaged commodities after aeration

Packaged commodity	Type of package construction	During fumigation				After aeration	
		24 hr		72 hr		24 hr	120 hr
		Outside	Inside	Outside	Inside		
Hungry Jack Mashed Potatoes	Painted paperboard carton	747	575	380	363	<0.3	-
Hungry Jack Buttermilk Pancake and Waffle Mix	Painted paperboard carton	747	560	380	355	<0.3	-
Baker Angel Flake Coconut	Heat sealed polyethylene pouch	747	363	380	401	<0.3	-
Carnation Dry Milk (20 qt)	Polymer overwrap coated paper with foil/polyethylene over paperboard	794	250	462	330	-	-
Quaker Quick White Grits	Paper bag - folded glued top	794	633	462	317	-	-
Sun Maid Raisins	Polyethylene coated painted paperboard carton	794	614	462	344	-	-
Cracker Jack	Polymer-paper-foil-paper-wax overwrap on paperboard carton	934	659	568	515	0.7-15.0	-
Aunt Jemima Buttermilk Pancake and Waffle Mix	Paper overwrap (tightly glued), paperboard carton	934	828	568	504	<0.3	-
Minute Fried Rice Mix	Painted paperboard carton	934	821	568	486	<0.3	-
Gaines Meal Dog Food	Printed paperboard carton	851	686	390	332	<0.3	-
Hungry Jack X-Light Pancake and Waffle Mix	Painted paperboard carton	851	667	390	319	<0.3	-

Table 3. Continued

Packaged commodity	Type of package construction	During fumigation				After aeration	
		24 hr		72 hr		24 hr	120 hr
		Outside	Inside	Outside	Inside		
Aunt Jemima Corn Meal Mix (2 lb)	Paper overwrap (tightly glued) paperboard carton	851	655	390	291	<0.3	-
Minute Rice	Painted paperboard carton	880	595	473	355	<0.3	-
Log Cabin Pancake Mix	Paper overwrap (tightly glued) paperboard carton	880	722	473	339	<0.3	-
Quick Quaker Oats	Paper overwrap, round paperboard carton	712	720	532	463	<0.3	-
Aunt Jemima Corn Meal (5 lb)	Paper bag carton with folded glued top	712	693	532	412	<0.3	-
Mahatma Rice (2 lb)	Heat sealed polyethylene pouch	780	655	679	605	5.1	<0.3
Gaines Burgers	Polymer overwrap printed paperboard carton	745	263	674	423	-	2.9
Top Choice Burger for Dogs	Printed paperboard carton with heatsealed coated polypropylene pouches	745	122	674	284	-	1.2
Nestle Sugar Cookie Mix	Painted paperboard carton with inner foil packets	760	126	650	325	-	70.9
Quaker 100% Natural Cereal	Printed paperboard carton with wax paper liner (heatsealed)	760	714	650	532	4.8	<0.3

INSECTICIDE RESISTANCE STUDIES

Investigators

J. L. Zettler and R. D. Jones

Stored-product insects have been exposed to severe and long-term pressures from insecticidal treatments aimed at insect control to reduce commodity losses by these insects. As a result, many stored-product insects have become extremely resistant to insecticides, particularly malathion, to the extent that control is often impossible with approved chemicals. The emergence of fumigant resistance has been slow to develop, but with major world dependence on fumigation, both as a routine disinfestation treatment and as a means of combating insecticide resistance, insecticide control by fumigation is becoming less effective.

The extent to which resistance can be overcome by increased dosages is severely limited by the level of residue acceptable in stored foodstuffs. This fact necessitates research on development of alternative insecticides and fumigants for use against resistant insects, including surveying resistance and cross-resistance levels, and assessing the susceptibility of wild strains of stored-product insects to promising alternative insecticides.

Pesticide susceptibility survey

Random insect collections were made from peanut warehouse and oilseed storage facilities in 16 different locations throughout the peanut-growing areas of the Southeastern U.S. In addition, food traps were placed in these facilities for a 5-wk. period. All collected strains are under culture in the laboratory and have been tested for resistance to malathion and dichlorvos (AI3-20738), and for baseline susceptibility to Actellic (pirimiphos-methyl) (AI3-27699).

Tables 4-7 show the results of these tests. Ten *Plodia* strains were so highly resistant to malathion that regression lines could not be determined (Table 4). Three of nine *Ephestia* strains showed malathion resistance so high it could not be measured.

Although dichlorvos has been used in peanut warehouses for several years, no cross-resistance is evident in any of the moth strains tested (Table 5). Only one *Plodia* strain (Eufaula) showed a slope flat enough to indicate the beginnings of dichlorvos-resistance development.

Generally, pirimiphos-methyl is quite toxic to the malathion-resistant moths (Table 6) although not as toxic as dichlorvos (Table 5). Strains of *P. interpunctella* are more susceptible than are strains of *E. cautella*, and several strains of the *C. cautella* show R/S factors above 2 compared with the standard susceptible laboratory strain. Only

one Plodia strain (Sylvania) had a regression line slope flat enough to indicate the beginnings of potential cross-resistance. All strains of T. castaneum tested were resistant to malathion (Table 7). There is no cross-resistance to dichlorvos and little or no cross-resistance (2-3 fold) to Actellic.

These data show that malathion resistance in these species of stored-product insects is more widespread and higher than ever recorded. Dichlorvos remains quite toxic to the pests with no cross-resistance having built up. Only slight indications of potential cross-resistance to Actellic is evident.

Future Plans

The insects collected in the survey will be tested for phosphine and methyl bromide resistance. Promising new insecticides will be tested against the malathion-resistant strains of stored-product insects to determine susceptibility levels. Cooperative efforts will be initiated for field testing the insecticide resistance kit.

Table 4. Probit analysis data for field-collected strains of *Plodia interpunctella* and *Ephestia cautella* against malathion.

Species	Strain	Probit data (mg./gm.)				
		LD_{50}	R/F	LD_{95}	R/F	Slope
P. interpunctella	Ocilla	>36	>114	--	--	--
	Matthews	>36	>114	--	--	--
	Statesboro (GK)	>36	>114	--	--	--
	Statesboro (R)	>36	>114	--	--	--
	Sylvania	>36	>114	--	--	--
	Eufaula	>36	>114	--	--	--
	Opp	>36	>114	--	--	--
	Douglas	>36	>114	--	--	--
	Milan	>36	>114	--	--	--
	Goshen	>36	>114	--	--	--
	Dudley	14.4	45.7	52.3	73.8	2.94
	Bainbridge	22.1	70.2	86.2	121.6	2.78
	Laboratory	0.315	1.0	0.709	1.0	4.68
Ephestia cautella	Douglas	>36	--	--	--	--
	Goshen	>36	--	--	--	--
	Camilla	>36	--	--	--	--
	Milan	9.23	3.0	35.08	2.8	2.84
	Sylvania	13.02	4.6	65.46	2.7	2.35
	Ft. Gaines	15.06	5.3	50.23	2.1	3.14
	Graceville	18.99	6.7	214.25	9.0	1.56
	Statesboro (GK)	20.46	7.2	116.95	4.9	2.18
	Andalusia	21.20	7.4	73.72	3.1	3.04
	Laboratory	2.85	1.0	23.87	1.0	1.78

Table 5. Probit analysis data for field-collected strains of *Plodia interpunctella* and *Ephestia cautella* against dichlorvos.

Species	Strain	Probit data (μg./gm.)				
		LD_{50}	R/F	LD_{95}	R/F	Slope
P. interpunctella	Matthews	22.2	<1.0	75.9	<1.0	3.07
	Ocilla	27.0	<1.0	75.3	<0.4	3.70
	Dudley	31.0	<1.0	89.0	<1.0	3.59
	Milan	32.8	<1.0	284.0	1.5	1.76
	Statesboro (R)	45.9	1.1	279.9	1.5	2.10
	Goshen	54.7	1.3	207.8	1.1	2.84
	Opp	56.5	1.4	392.6	2.1	1.95
	Bainbridge	62.6	1.5	445.3	2.4	1.93
	Sylvania	67.1	1.6	193.3	1.0	3.58
	Eufaula	79.7	1.9	1086.5	5.8	1.45
	Laboratory	41.7	1.0	186.9	1.0	2.52
E. cautella	Ft. Gaines	21.2	<1.0	69.6	<1.0	3.19
	Milan	21.7	<1.0	64.4	<1.0	3.49
	Statesboro (GK)	22.5	1.0	55.4	<1.0	4.20
	Moultrie	22.8	1.0	101.2	1.2	2.54
	Douglas	24.6	1.1	101.2	1.2	2.68
	Andalusia	27.8	1.1	70.0	<1.0	4.10
	Graceville	29.0	1.3	76.5	<1.0	3.91
	Sylvania	30.4	1.3	85.3	1.0	3.67
	Laboratory	22.8	1.0	87.0	1.0	2.83

Table 6. Probit analysis data for field-collected strains of *Plodia interpunctella* and *Ephestia cautella* against Actellic.

Species	Strain	Probit data (µg./gm.)				
		LD_{50}	R/F	LD_{95}	R/F	Slope
P. interpunctella	Douglas	73.0	<1.0	271.2	<1.0	2.89
	Dudley	93.7	<1.0	415.0	1.3	2.54
	Milan	103.6	<1.0	304.5	<1.0	3.51
	Eufaula	123.5	1.1	306.7	1.0	4.16
	Matthews	167.1	1.4	326.3	1.0	5.66
	Opp	173.5	1.5	377.0	1.2	4.88
	Goshen	201.8	1.7	386.6	1.2	5.82
	Sylvania	217.9	1.9	1611.0	5.0	1.89
	Bainbridge	246.7	2.1	543.3	1.7	4.79
	Ocilla	283.4	2.4	1357.7	4.2	2.42
	Statesboro (R)	470.0	4.1	1720.4	5.4	2.92
	Laboratory	116.0	1.0	321.0	1.0	3.72
E. cautella	Milan	290.1	1.7	973.5	1.8	3.13
	Sylvania	290.5	1.7	744.1	1.4	4.03
	Andalusia	333.4	2.0	733.0	1.4	4.81
	Moultrie	337.0	2.0	695.3	1.3	5.23
	Ft. Gaines	378.7	2.2	1749.0	3.2	2.48
	Graceville	385.1	2.3	733.1	1.4	5.88
	Statesboro (GK)	412.9	2.4	800.7	1.5	5.72
	Camilla	596.0	3.5	1059.1	2.0	6.59
	Laboratory	168.9	1.0	538.5	1.0	3.27

Table 7. Probit analysis data for field-collected strains of *Tribolium castaneum* tested against malathion, dichlorvos, and Actellic.

Strain	Probit data				
	LD_{50}	R/F	LD_{95}	R/F	Slope
			Dichlorvos (μg./gm.)		
Fort Gaines	69.0	1.4	205.7	<1.0	3.47
Bainbridge	54.9	1.1	196.6	<1.0	2.97
Ocilla	64.4	1.3	168.6	<1.0	3.93
Graceville	138.7	2.7	254.5	<1.0	6.17
Laboratory	51.0	1.0	436.0	1.0	1.72
			Actellic (μg./gm.)		
Ocilla	3.4	<1.0	93.3	1.0	1.15
Fort Gaines	59.8	2.1	188.6	2.1	3.30
Graceville	73.0	2.6	274.3	3.1	2.86
Laboratory	28.0	1.0	89.0	1.0	3.31
			Malathion (mg./gm.)		
Fort Gaines	0.18	3.5	0.68	3.7	2.81
Bainbridge	2.7	53.6	5.7	31.1	5.07
Ocilla	3.5	70.0	10.4	57.0	3.49
Goshen	6.5	129.6	19.0	104.5	3.52
Laboratory	0.05	1.0	0.18	1.0	2.92

PROTECTIVE WAREHOUSE TREATMENTS

Investigators

L. M. Redlinger, H. B. Gillenwater, and G. Eason

Development and evaluation of warehouse space treatments

A major portion of the military's pest management program for the prevention and control of stored-product insects in subsistence warehouses involves the utilization of insecticide vapor/aerosols as space treatments. Dichlorvos (AI3-20738) is presently used for this purpose but it is available only as a 5% formulation. Research has shown that a new pesticide pirimiphos-methyl (AI3-27699) has a 6-fold potential advantage over dichlorvos. It is formulated as a high concentrate EC (7 lbs. a.i./gal.) that can be applied as either a low-volume or water-base vapor/aerosol. Large-scale warehouse tests have been completed for establishing residue data on packaged subsistence items. The chemical company has submitted their package of data to the Environmental Protection Agency for labeling pirimiphos-methyl. The package as submitted to EPA did not have sufficient data relating to the neurotoxicity of pirimiphos-methyl for them to base a decision. EPA will reconsider labeling as soon as sufficient information is available for a determination to be made.

Tests were conducted in warehouses at the Jacksonville Naval Air Station to assess the potential of resmethrin (AI3-27474) and permethrin (AI3-29158) as space treatments for subsistence warehouses. Applications were made using inplace-dispensers (Micro-Gen Equipment Corporation, SPACE II and S-IV units) following methods and procedures as previously described for the pirimiphos-methyl studies. Resmethrin was applied at 17.7 mg./m.^{3} and 35.4 mg./m.^{3} (0.5 g. a.i. and 1 g. a.i./1,000 ft.^{3}). Permethrin was applied at 35.4 mg. a.i./m.^{3}. Each compound was applied both as a ULV concentrate with the SPACE II generator and as a 5% EC mixture in water with the S-IV units.

Test results showed that distribution and biological efficacy were consistently better with the SPACE II generator than with the S-IV generators. Permethrin applied as a ULV with the SPACE II generator gave complete control of all tests insects but not when applied as a 5% EC with the S-IV units. Resmethrin was not as effective against confused flour beetle adults as was permethrin. Both resmethrin and permethrin appeared to be more effective against black carpet beetle larvae than against confused flour beetle adults.

Future Plans

Research on chlorpyrifos-methyl during the past several years has shown that it has potential both as a protective treatment for stored commodities and as a residual-type treatment in warehouses for the control of stored-product insects. Chlorpyrifos-methyl is an organophosphate compound which kills insects on contact or by ingestion. Its broad

spectrum of insecticidal activity and low mammalian toxicity make it a promising insecticide for many uses. The chemical company is actively pursuing the labeling of this compound.

Tests will be conducted for the evaluation of chlorpyrifos-methyl as a space treatment for warehouses. If this compound continues to show promise, follow-up studies will be conducted in large warehouses to confirm application rates, frequency of application, and to obtain residue data and information on safe reentry of the warehouse.

Investigators

L. M. Redlinger, H. B. Gillenwater, G. Eason, and R. A. Simonaitis

Development and evaluation of warehouse residual treatments

Tests were conducted to evaluate the residual effectiveness of Killmaster(R) II, a controlled-release, 2% chlorpyrifos (AI3-27311) formulation applied as a residual spray on selected building material surfaces. Panels of concrete, painted (latex, flat) concrete, plywood, painted (alkyd flat, oil base) plywood, brick, galvanized metal and painted (battleship gray) steel were sprayed at ca. 100 $\mu g./cm.^2$ (100 $mg./ft.^2$) and held for testing in a room maintained at 27 ± 1°C and 65 ± 3% RH. Panels were treated with malathion at the same rate as a standard for comparison. Confused flour beetle (CFB) adults and black carpet beetle (BCB) larvae were exposed to the treated surfaces for 24 hours at selected time intervals after treatment. Residual effectiveness 9 days after treatment was about the same for Killmaster II as for malathion against both CFB adults and BCB larvae, on all surfaces, except concrete. Malathion lost its residual effectiveness on concrete against both species within a few days whereas Killmaster II was effective for 9 days on concrete against CFB adults but not BCB larvae.

The same panels were retreated after ca. 3 months to simulate a second warehouse treatment to see if the residue would enhance or add to the overall residual effectiveness. During the first 14 days after treatment, Killmaster II and malathion were about equally effective against CFB adults on all building surfaces except concrete. Malathion became ineffective on concrete in less than 7 days. Killmaster II lost its effectiveness after 21 days on concrete and its overall effectiveness on the remaining building surfaces was less than malathion.

The chlorpyrifos content of Killmaster I and II formulations was determined by chemical analysis of samples from different batches submitted by DVECC, NAS, Jacksonville, Florida. The mean percentage of chlorpyrifos in Killmaster I was 0.9 ± 0.03% with a range from 0.81 to 1.03%. Killmaster II had a mean of 2.21 ± 0.09% and a range of 1.78 to 2.31% chlorpyrifos.

Future Plans

Several commercial formulations of promising insecticides will be evaluated as residual-type sprays on various substrates which are encountered in warehouse construction. The compounds showing the greatest efficacy and potential for marketing will be further evaluated as a residual crack and crevice or spot treatment under warehouse conditions. These experiments will be correlated with space treatments in the development of an integrated pest management system for military subsistence warehouses.

PROTECTIVE CONTAINERS

PACKAGE MATERIALS AND CONSTRUCTION

Investigators

H. A. Highland and L. D. Cline

The 12th generation of confused flour beetles, Tribolium confusum, reared on a synergized-pyrethrins-treated medium (50:500 p.p.m. pyrethrins: piperonyl butoxide) was tested for resistance to synergized pyrethrins and for immunity to the repellent action of synergized pyrethrins on paper. Resistance to the synergized piperonyl appears to be only slightly lighter than it was one year ago when the 6th generation was tested. They are now ca. 5 times more resistant than the standard susceptible laboratory strain. Tests in which insects were given a choice between untreated and treated kraft paper (5:50 mg./sq. ft. of pyrethrins: piperonyl butoxide) showed that more stressed insects were found on the treated paper than were insects reared on untreated medium.

Tests were conducted in which flour beetles were placed on untreated flour beetle medium and on synergized-pyrethrins-treated medium in opposite ends of a 12" trough, touching at their interface. The insects reared on the treated medium were less repelled by the treated medium than were insects from the susceptible laboratory strain. In every case at 1 and 7 days of exposure, there were more stressed insects on the treated side than insects reared on untreated medium. At the highest of the 3 levels of treatment (50:500 p.p.m. pyrethrins: piperonyl butoxide), the repellency of synergized pyrethrins was apparent; none of the laboratory strain of T. confusum were on the treated side after 1 or 7 days' exposure while ca. 21% of the stressed insects were on the treated side after 1 day and ca. 4% after 7 days.

Tricalcium phosphate (TCP) has been shown to be an insect suppressant as well as a calcium food additive in certain cereals. When TCP is added to cereals such as bulgur or sorghum grits, the TCP settles out and may cause dusting. To eliminate the settling and dusting, soy oil was added to cornmeal, bulgur and sorghum grits along with TCP. TCP alone prevented survival of seeding adults or progeny of 3 species on these cereals, but L. serricorne matured on cornmeal with TCP (table 2). The oil minimized settling and dusting but also reduced the effectiveness of the TCP.

During storage and shipment, insect resistant bags may be handled many times before they are opened by the user. Consequently seams and closures may loosen and occasionally bags may become infested, or insects may inadvertently be packaged along with the commodity. These hidden infestations may constitute foci that enable insects to spread to other packages. Therefore tests were conducted to determine if lesser grain borers (R. dominica) and cigarette beetles (L. serricorne) can penetrate

through the walls of paper bags treated with permethrin or synergized pyrethrins. Adults and larvae of *L. serricorne* and adult *R. dominica* were placed in small multiwall paper bags coated with permethrin or with pyrethrins synergized with piperonyl butoxide. The bags were made of 4 or 5 plies of kraft paper, and some also contained polyethylene film or greaseproof paper plies. *L. serricorne* larvae and *R. dominica* adults penetrated out of permethrin-treated and pyrethrins-treated bags within 2 weeks and they penetrated 53-100% of the bags within 10 weeks. Adult *R. dominica* generally formed fewer holes than did *L. serricorne* larvae. No bags were penetrated by *L. serricorne* adults. These results indicate that both species are likely to bore out of treated bags in storage, providing ingress for other species and a reservoir of insects to attack other nearby packages.

Future Plans

Determine the smallest openings through which (1) females of various stored-product insects can oviposit and (2) newly emerged larvae can pass. Determine the time required for *Rhyzopertha dominica* to penetrate various numbers of plies of 1-mil packaging films. Continue testing *Tribolium confusum* that have been stressed by confinement on synergized pyrethrins for tolerance to repellent and toxic action of the pesticide. Determine if *Bracon hebetor* and *Nemeritis canescens* can prevent *Ephestia cautella* from spreading from infested packages to uninfested packages. Evaluate the insect resistance of newly designed packages for prepared biscuit mix and for institutional-size cake mixes.

SIMULATED OR PRACTICAL STORAGE STUDIES

Investigators

H. A. Highland and L. D. Cline

Development of a shipping bag that resists insect infestations for at least 2 years has been a recommendation of the AFPMB for several years. Preliminary tests showed that permethrin was very promising. Therefore, long-term, large-scale tests are in progress in Egypt and in Savannah to determine (1) the efficacy of permethrin as an insect resistant treatment on multiwall paper bags, (2) the effectiveness of tricalcium phosphate (TCP) as an insect suppressant in instant CSM (ICSM) stored in insect-resistant treated paper bags, untreated woven polypropylene bags, and in untreated paper bags, (3) the migration of permethrin from the outer treated ply into the untreated inner plies of empty stored bags, and (4) the effectiveness of a greaseproof barrier ply in preventing movement of permethrin from the outer treated ply into the contents of the bags.

Results of these 12-month storage tests show that permethrin-treated bags were more resistant to infestation than were synergized pyrethrins-treated or untreated bags. Untreated woven polypropylene bags were more susceptible to infestation than were treated or untreated paper bags.

There were generally fewer insects in ICSM with TCP than in ICSM with other calcium salts. Even after 12-months of storage, when very large numbers of insects were found in infested bags, there were fewer insects in the ICSM with TCP.

With one exception, no detectable permethrin were found in ICSM stored for 11 months in treated bags. A permethrin residue of 0.3 ppm was indicated in one sample, but this is considered an anomaly since no detectable residues were found in subsequent samples. During this period, ICSM from synergized pyrethrins-treated bags contained up to 3.3 ppm of piperonyl butoxide.

After 8 months of storage, only traces of permethrin were found on the inner plies of empty treated bags having greaseproof paper barrier plies. There was no detectable loss of permethrin from the outer treated plies. After 2 months of storage, about 50 percent of the piperonyl butoxide on empty, synergized pyrethrins-treated bags was found on the inner plies. During 3 months of storage, there was no detectable loss of permethrin from the outer ply of empty bags without greaseproof liners.

The large amount of retail shelf space occupied by dry pet food and the frequent proximity to other infestible food constantly makes pet food a possible reservoir of insects in retail stores. Pet food is also frequently circumstantially incriminated as the source of infestation in

warehouses. Department of Defense warehouses commonly contain infested pet food, and SEA-AR has been asked to help alleviate this problem. Use of an insecticide-treated film overwrap baler for bags of dry pet foods may prevent infestation of the bags from nearby sources; also, the treated film may prevent insects from escaping the baled bags to infest other foods. Bags of dog food have been packed in chloropyrifos-methyl-treated film balers. The bales will be exposed to insects in a simulated warehouse. Periodically the dog food will be examined for insects and for residues of the insecticide treatment.

Future Plans

Complete large-scale tests to determine the insect resistance of permethrin-treated paper bags during long-term storage. Conduct storage tests to determine the insect resistance of chloropyrifos-methyl-treated polyethylene film baler overwraps on small bags of dry pet food.

EVALUATION OF THE INSECT RESISTANCE OF AND THE ABILITY TO FUMIGATE MILITARY SUBSISTENCE CONTAINERS NATICK PROJECT 78-149

Investigators

H. A. Highland and L. D. Cline

Blacklight (BL) and whitelight (WL) trapping in empty, insect-tight, 1,500 cu. ft. rooms for six species of stored-product moths was reported last year. In the second phase, three pallets (4 x 4 ft.) loaded with empty corrugated cases to a height of ca. 5 ft. were placed in the center of the test rooms to create a physical and visual barrier between the insects and the light traps. Table 8 compares the data from BL and WL traps in empty rooms and rooms with pallets. WL trap catches of *Ephestia cautella*, *Anagasta kuehniella*, *Corcyra cephalonica*, and *Tineola bisselliella* were similar in empty and partially-filled rooms. Catches of *Plodia interpunctella* and *Sitotroga cerealella* in WL traps were dramatically reduced in rooms with loaded-pallet barriers. In BL tests fewer adults of *P. interpunctella*, *A. kuehniella*, and *T. bisselliella* were caught in rooms with pallets than in empty rooms. Catches of *E. cautella*, *S. cerealella*, and *C. cephalonica* in BL traps were similar in empty and partially-filled rooms.

Light-trapping studies have been completed to determine the response of three parasitic wasps, *Anisopteromalus calandrae*, *Bracon hebetor*, and *Nemeritus canescens*, and a predaceous bug, *Xylocoris sordidus*, to BL or WL traps (Table 9). Tests showed that *B. hebetor* was very responsive to BL and WL traps. Catches of *A. calandrae* were somewhat lower than catches of *B. hebetor*. *N. canescens*, a species that consists of parthenogenetic females, showed a very strong preference for BL (75.3% trapped the first night increasing to 88.4% the second night). Catches of *N. canescens* in the WL trap were only 30% the first night increasing to 60.9% the second night. *X. sordidus* was only weakly attracted to either light source.

Tests to determine the effectiveness of BL or WL traps to detect the presence of six species of stored-product Coleoptera (beetles and weevils) in empty rooms have been completed. Generally, the percentage of the insects (1-7 days old) trapped was low (less than 10% for *Sitophilus zeamais*, *Dermestes maculatus*, *Callosobruchus maculatus*, and *Tribolium castaneum*). Ca. 30% of *Trogoderma variabile* adults responded to the light sources with nearly twice as many males being trapped than females. Of the species tested, *Cathartus quadricollis* responded best (nearly 60% trapped). There was little difference in the percentage of each species caught in BL or WL traps.

Future Plans

This project expired June 30, 1980; however, some additional limited testing will be conducted, depending on availability of resources.

Table 8. Average percentage of released moths caught in light traps over the entire adult life span; results are from three or more replicates

Species	Light source	Insects (pct) trapped in	
		Empty rooms	Rooms with pallets
E. cautella	WL	87	81
	BL	63	65
P. interpunctella	WL	79	57
	BL	82	60
S. cerealella	WL	64	34
	BL	52	47
A. kuehniella	WL	20	24
	BL	52	35
C. cephalonica	WL	12	14
	BL	17	12
T. bisselliella	WL	54	53
	BL	64	15

Table 9. Percentage of three parasitic wasps and a predaceous bug caught in light traps after 1 week; results are an average of four replicates

Species	Insects trapped in	
	Whitelight traps	Blacklight traps
A. calandrae	64.4	64.3
B. hebetor	92.3	84.8
N. canescens	60.9	88.4
X. sordidus	1.0	9.1

Table 10. Survival of seeding adults and/or production of progeny on cereals treated with tricalcium phosphate

Test insect	Treatment		Survival of seeding adults or production of progeny on 1/		
	TCP	Oil	SFT	SFSG	SFCM
T. castaneum	0	0	2/ +	+	+
	2	0	-	-	-
	2	1	-	+	+
R. dominica	0	0	+	+	+
	2	0	-	-	-
	2	1	+	+	+
L. serricorne	0	0	+	+	+
	2	0	-	-	+
	2	1	+	+	+
E. cautella	2	0	-	-	-
	2	1	-	+	+

1/ SFB: soy fortified bulgur; SFSG: soy fortified sorghum grits; SFCM: soy fortified cornmeal.

2/ +: live insects found; -: no live insects found.

EVALUATION OF THE INSECT RESISTANCE OF POLYMER FILM POUCHES AND COMMERCIALLY AVAILABLE ALTERNATIVE PACKAGES FOR MILITARY RATIONS NATICK PROJECT 80-457

Investigators

H. A. Highland and L. D. Cline

Procurement plans for the meal, ready to eat (MRE) include the immediate purchase of about 24 million MRE's packed in 10-mil polyethylene (PE) film pouches. These will be stored for 2 years at about 40°F., which will prevent attack by insects. During this period the PE pouch is to be evaluated for resistance to insect attack. Additionally, other commercially available films and alternative packages will also be evaluated. Data provided by this research will provide input for the selection of appropriate packaging for future procurement of MRE's.

Research Objective No. 1. Determine in closely controlled laboratory tests the resistance to insect attack of heat-sealed, 10-mil, low-density polyethylene film pouches containing MRE's.

These tests are being conducted in plastic chambers with six pouches per chamber. Each chamber is infested with *Rhyzopertha dominica* (lesser grain borer), *Trogoderma variabile*, *Lasioderma serricorne* (cigarette beetle), or *Tribolium castaneum* (red flour beetle), along with appropriate food media. At this writing one examination has been conducted (1-month exposure to *T. variabile*). No pouches were penetrated.

Research Objective No. 2. Determine in semipractical, long term tests (2 years or more) the resistance to insect attack of these pouches when packed in fiberboard shipping cases or when unprotected by cases, and when exposed to insects having access to food sources.

These cases and pouches are being exposed to a general population of insects in a heavily infested, simulated warehouse. One pouch from one case was penetrated during 2 months of storage.

Research Objective No. 3. Determine in semipractical, long-term tests (2 years or more) the resistance to insect attack of these pouches when packed in fiberboard shipping cases or when unprotected by cases, and when exposed to insects not having access to food sources.

These cases and pouches are being exposed to four beetle species and two moth species in a simulated warehouse having no food media for the insects. Insects are placed in the room at 6-week intervals. No penetrations were found after 2 months of storage.

Research Objective No. 4. Determine in closely controlled laboratory tests the resistance to insect attack of alternative containers for MRE's.

The following alternative packages are being exposed to insects as described in Research Objective No. 1: composite can, 15-mil PE film pouch, 5-mil PE film pouch and PE/nylon film pouch. No results are available.

Research Objective No. 5. Determine in semipractical, long-term tests (2 years or more) the resistance to insect attack of alternative containers for MRE's in fiberboard shipping cases and when unprotected by cases.

If available, alternative packages described in Research Objective No. 4 will be exposed to a general population of insects in a heavily infested, simulated warehouse.

Future Plans

Continue tests described above.

EVALUATION UNDER ACTUAL FIELD CONDITIONS OF THE INSECT RESISTANCE OF POLYETHYLENE FILM POUCHES FOR MRE'S NATICK PROJECT 80-467

Investigators

H. A. Highland and L. D. Cline

Procurement plans for the MRE's include the immediate purchases of about 24 million MRE's packed in 10-mil polyethylene (PE) film pouches. These will be stored for 2 years at about 40°F., which will prevent attack by insects. During this period, the pouches are to be evaluated for resistance to insect attack. Closely controlled laboratory tests are being conducted at the Stored-Product Insects Research and Development Laboratory (SPIRDL), SEA-USDA, Savannah, Georgia. The investigations described here will be conducted with assembly-line packages of MRE's shipped in normal military channels and stored in military subsistence warehouses.

Research Objective. Determine, in closely monitored field tests, the resistance to insect attack of MRE's packed in 10-mil low density polyethylene film pouches. These tests will be conducted simultaneously with closely controlled laboratory tests being conducted at the SPIRDL, Savannah, Georgia.

MRE's will be packed in 10-mil heat-sealed polyethylene film pouches. The pouches will be packed in fiberboard shipping cases and palletized. Nine pallets of MRE's (eight test pallets plus one extra to allow for damage, pilferage, etc.) will be shipped to DOD warehouses in Panama, Alaska, Italy, the Philippines, and Mechanicsburg, Pennsylvania. All shipping and storage conditions will duplicate, insofar as possible, those encountered in routine military food shipments. Pouches will be examined for insect damage at approximately 6-month intervals for 2 years. The cases will be repacked for additional storage periods if appropriate.

PROTECTION OF FABRICS

New mothproofing treatments are needed to replace chlorinated insecticides previously used to protect woolens and other animal fibers against insect damage. Although there has been a decline in the use of wool due in part to increased use of synthetic fibers, the energy shortage may well reverse the decline and result in increased use of wool and other natural fibers. Because the manufacture of synthetics depends heavily on the use of fossil fuel, a high priority on energy conservation will bring back the use of more wool. Therefore, new effective mothproofing treatments will be needed.

In recent years, research at this laboratory has resulted in three synergized pyrethrins formulations, one resmethrin formulation and two combination formulations of tetramethrin and d-phenothrin, being registered by EPA for home use as pressurized sprays. However, a more "permanent" mothproofer that can be applied during dyeing or some other phase of wet-processing is needed. Research to date with permethrin indicates that this synthetic pyrethroid has all of the performance characteristics of a "permanent" mothproofer. Based on the results of a cooperative test conducted with the U.S. Army Natick Research and Development Command and Fairfield American Corporation, Fairfield petitioned EPA to label permethrin as a mothproofer for mill use.

During the past year, the fabric protection project obtained a reflection meter. The addition of this piece of equipment will allow us to more effectively evaluate promising mothproofing compounds by eliminating guesswork to detect staining.

Ongoing research on fabric protection is of interest to the Armed Forces Pest Management Board because DOD maintains large stocks of wool and wool/synthetic blend fabrics as well as clothing made of these fabrics. Also, feathers, fur items, felt, and other keratinous materials are subject to fabric-insect attack.

INVESTIGATION OF CANDIDATE MOTHPROOFERS

Investigators

J. H. Lang, R. E. Boatright, and R. E. Bry

Compounds appearing promising in preliminary tests

Because we have been requested not to include information in any reports on new compounds whose identity is coded until the period of confidence has expired, new compounds are identified only by "S" number (Savannah number).

A total of 166 compounds were evaluated as candidate mothproofers. The bulk of these compounds were 158 candidate repellents received from SEA's Organic Chemical Synthesis Laboratory, Beltsville, Maryland. The remaining compounds were five organophosphorus and three synthetic

pyrethroid insecticides. All of the compounds were applied to woolen cloth as acetone solutions. In addition, three of the insecticidal compounds were applied to the cloth from emulsion baths at 130°F. All of the treated cloths were subjected to black carpet beetle larvae in standard CSMA feeding tests.

Forty-five of the repellents provided satisfactory protection against black carpet beetle larval feeding damage at deposit levels of 0.5 and 3.0% by weight. An additional 64 repellents satisfactorily protected the cloth at the 3.0% deposit level only. None of the repellents were particularly toxic to the insects in these evaluations. However, in most cases where mortality did occur, the inability of the insects to complete the molting process was indicated.

OP compounds S-3596, S-3597, and S-3598 satisfactorily protected woolen cloth at both 0.5 and 3.0% by weight. However, no difference in the degree of protection was noticed. Additional tests with these compounds are planned.

Tests to determine the minimum effective level (M.E.L.) of OP compounds S-3528 and S-3529, and SP compounds S-3551 and S-3552 needed to protect woolen cloth against black carpet beetle larvae were conducted. The M.E.L. for both OP compounds was found to be between 0.031 and 0.063% by weight; the M.E.L. for both SP compounds fell between 0.002 and 0.004% by weight. SP compound S-3551 also satisfactorily protected woolen cloth against webbing clothes moth larval damage at a deposit level of 0.008% by weight.

OP compound S-3528 and SP compounds S-3551 and S-3552 were formulated into emulsifiable concentrates and applied to woolen cloth from aqueous baths at 130°F. Results showed that a bath concentration of 0.005% by weight of OP compound S-3528 rendered borderline protection from black carpet beetle larvae before any cleansing manipulations and after one drycleaning. A bath concentration of 0.03% by weight provided mid-range protection after three drycleanings. No protection was afforded cloths treated with this compound after they were washed once. Bath applications of both SP compounds equally protected woolen cloth from black carpet beetle larval damage before cleansing manipulations. However, S-3551 was more effective than S-3552 in protecting the cloth after cleansing manipulations. SP compound S-3551 provided protection at a bath concentration of 0.03% by weight after two washings and three drycleanings.

Investigations were initiated this year with another SP compound, fenvalerate (AI3-29235). Tests are in progress to determine the M.E.L. of fenvalerate needed to protect woolen cloth against larvae of the black carpet and furniture carpet beetles, and the webbing clothes moth. Results to date indicate that a deposit level between 0.002 and 0.004% by weight will protect against black carpet beetle larvae, while a deposit level between 0.001 and 0.002% by weight will protect against webbing clothes moth larvae. A much higher deposit level appears needed for protection against furniture carpet beetle larvae.

Future Plans

Screening of new compounds will be continued. Particular consideration will be given to compounds having a low order of mammalian toxicity. When possible, compounds having promise as acetone solutions will be tested as emulsifiable formulations.

DEVELOPMENT OF MOTHPROOFING FORMULATIONS AND APPLICATION TECHNIQUES

Investigators

R. E. Bry, R. E. Boatright, J. H. Lang, and R. A. Simonaitis

Sumithrin(R) oil-solution spray

Cloth sprayed with an oil-solution pressurized spray formulation of Sumithrin (AI3-29063) was satisfactorily protected against feeding damage by larvae of the black and furniture carpet beetles and the webbing clothes moth after the treatments had aged 6 months. The formulation was also very effective as a direct contact spray against both adults and larvae of the aforementioned fabric insects. The cooperator, McLaughlin Gormley King Company plans to label this formulation as a fabric protectant for home use.

Ovicidal properties of permethrin

Eggs of the black carpet beetle and the webbing clothes moth were exposed on woolen cloth treated with permethrin (AI3-29148) at rates of 0.01, 0.02, 0.05, and 0.10% by weight of the cloth. All dosage levels tested were lethal to eggs of the clothes moth but had no effect on eggs of the black carpet beetle. However, mortality was 100% at all levels tested for first instars of the black carpet beetle.

Permethrin washer and dryer applications

Permethrin applications were made to 4-lb. washer loads of woolen cloth as follows: (1) Permethrin EC was applied simultaneously with a home-laundry fabric softener in the rinse cycle in an automatic washer, (2) permethrin EC was applied in the wash cycle when the wool was washed with a liquid cold water detergent, (3) a fabric softener sheet was impregnated with technical permethrin and placed in the washer with the wool at the beginning of the last rinse cycle, and (4) a fabric softener sheet impregnated with technical permethrin was placed in a home dryer with a load of washed wool and the load was dried for ca. 30 minutes using the permanent press drying cycle. Permethrin residues ranged from 0.043 to 0.064% by weight of the cloth. Cloth from all applications was satisfactorily protected against feeding damage by larvae of black and furniture carpet beetles and the webbing clothes moth.

Fenvalerate oil and water-based spray studies

Research was initiated with oil and water-based pressurized spray formulations of fenvalerate (AI3-29235) to determine if this pyrethroid may be developed as a spray application for home protective treatment for woolens. Results to date indicate that these formulations appear promising as a fabric protectant for home use.

Synergized permethrin studies

Aging studies were completed with furniture carpet beetle larvae exposed to woolen cloths treated with permethrin at 0.0025 and 0.005% by weight synergized with piperonyl butoxide at ratios of 1:1, 1:4, and 1:8. At the 0.005% by weight deposit level, a 1:1 permethrin:piperonyl butoxide ratio protected the cloth initially; however, after 6 months' aging, a 1:4 ratio was necessary to satisfactorily protect the cloth. A ratio of 1:8 was necessary to protect the cloth at the 0.0025% deposit level; this ratio also protected the cloth after 3 months' aging, but failed to provide protection after 6 months.

Registration status of permethrin

Information obtained at the Savannah laboratory with an aqueous pressurized spray formulation of permethrin was used by cooperator, Fairfield American Corporation to petition EPA to label permethrin as a protectant for stored woolens in the home. Also, information obtained in a pilot-plant application of permethrin conducted in cooperation with the U.S. Army Natick Research and Development Command and Fairfield American Corporation was used by Fairfield to petition EPA to label permethrin as a permanent-type mothproofer. Since progress on all permethrin registrations has been slowed down because of results obtained in oncogenicity studies, no label has been obtained for either use. EPA is expected to make a decision on permethrin early in CY 1981.

Feeding studies with synthetic fabrics

Previous studies with non-intimate wool/synthetic blends have shown that no damage was inflicted to the synthetic portion. However, recent reports from various trade members indicated damage to synthetics by clothes moths and carpet beetles. Studies were initiated with 7 synthetic fabrics purchased locally to verify these observations. Three fabrics were 100% acetate, nylon or polyester. The remaining fabrics were various blends of nylon, polyester, acetate, rayon, triacetate and flax. No significant damage was noticed with the 100% fabrics. The blends did show some very slight to slight damage. Mortality ranged from 0% among black carpet beetles to 23% among furniture carpet beetles.

Future Plans

Studies in progress on the ovicidal properties of Sumithrin will be continued. Ongoing research with fenvalerate will be completed and studies will be initiated to determine if this pyrethroid may be developed as a permanent-type mothproofer. Contingent upon the status of permethrin registrations, additional research will be conducted with this pyrethroid.

INVESTIGATIONS WITH INSECT-DETECTION TECHNIQUES

INSECT-DETECTION TECHNIQUES

Investigator

W. A. Bruce

Currently, research on the development of techniques for the detection of hidden infestations of insects involves computer controlled, $IRCO_2$ gas analysis in bulk commodity storage. Components have been assembled and testing should begin early in 1981.

Future Plans

Advanced technologies such as thermal imaging, high intensity xray, photo-acoustic spectroscopy, and others will continue to be monitored through the literature and their possible application to the detection of hidden insects will be determined whenever feasible.

PUBLICATIONS

Arbogast, Richard T., G. Leonard LeCato, and Richard Van Byrd. 1980. External morphology of some eggs of stored-product moths (Lepidoptera: Pyralidae, Gelechiidae, Tinedae). Int. J. Insect Morphol. & Embryol. 9: 165-77.

Barrer, P. M., and E. G. Jay. 1980. Laboratory observations on the ability of Ephestia cautella (Walker) (Lepidoptera: Phycitidae) to locate, and to oviposit in response to a source of grain odour. J. Stored Prod. Res. 16: 1-7.

Brower, John H. 1980. Comparative radiosensitivity of field-collected and laboratory strains of the Indian meal moth. J. Ga. Entomol. Soc. 15(4): 439-45.

Brower, John H. 1980. Inheritance of partial sterility in progeny of irradiated males of Ephestia cautella (Lepidoptera: Pyralidae) and its effect on theoretical population suppression. Can. Ent. 112: 131-40.

Brower, John H. 1980. Irradiation of diapausing and nondiapausing larvae of Plodia interpunctella: Effects on larval and pupal mortality and adult fertility. Ann. Entomol. Soc. Am. 73: 420-6.

Brower, John H., and Leonard Jurd. 1980. Mortality and sterility of the Indian meal moth and the red flour beetle treated with eight candidate chemosterilants. J. Ga. Entomol. Soc. 15(4): 390-8.

Brower, John H. 1980. Reduction of almond moth populations in simulated storages by the release of genetically incompatible males. J. Econ. Entomol. 73(3): 415-8.

Bruce, W. A., and G. L. LeCato. 1979. Pyemotes tritici: A potential biological control agent of stored-product insects. In Recent Advances in Acarology, Vol. I, 631 p.

Bruce, W. A., and G. L. LeCato. 1980. Pyemotes tritici: A potential new agent for biological control of the red imported fire ant, Solenopsis invicta (Acari: Pyemotidae). Internat. J. Acarol. 6(4): 271-4.

Bruce, W. A., P. T. M. Lum, H. C. F. Su, R. E. Bry, and R. Davis. 1980. Protection of insect pheromones from degradation by ultraviolet radiation. U.S. Defensive Publication, T998,012.

Bruce, W. A., P. T. M. Lum, H. C. F. Su., R. E. Bry, and R. Davis. 1980. Protection of insect pheromones from degradation by ultraviolet radiation. U.S. Defensive Publication, T998,013.

Bry, R. E., R. E. Boatright, and J. H. Lang. 1980. Ovicidal effect of permethrin against the black carpet beetle and the webbing clothes moth. J. Econ. Entomol. 73(3): 449-50.

Bry, Roy E. 1980. Protecting woolens against clothes moths and carpet beetles. SEA, USDA Home and Garden Bulletin 113. 8 p.

Bry, Roy E. 1980. Protecting home cured meat from insects. SEA, USDA Home and Garden Bulletin 109. 6 p.

Bry, R. E., R. A. Simonaitis, R. E. Boatright, and J. H. Lang. 1980. Pyrethroid combination sprays effective as fabric protectant. Soap/Cosmet./Chem. Spec. 56(3): 35-7, 59-61.

Davis, Robert. 1977. Commodity Storage Manual. The Refrigeration Research Foundation. 2 p. Robert Davis, 1980. (Revision)

Gillenwater, H. B., L. Jurd, and L. L. McDonald. 1980. Repellency of several phenolic compounds to adult Tribolium confusum. J. Ga. Entomol. Soc. 15(2): 168-75.

Ignatowicz, Stanislaw, and Jan Boczek. 1979. Sterility induced in "copra mite," Tyrophagus putrescentiae by iodine salts. Rec. Adv. Acar. 1: 285-90.

Jay, Edward. 1980. Methods of applying carbon dioxide for insect control in stored grain. Advances in Agricultural Technology, Southern Series, No. 13, USDA.

LeCato, G. L., and R. T. Arbogast. 1979. Functional response of Xylocoris flavipes to Angoumois grain moth and influence of predation on regulation of laboratory populations. J. Econ. Entomol. 72(6): 847-9.

Lum, P. T. M., and R. T. Arbogast. 1980. Ultrastructure of setae in the spermathecal gland of Plodia interpunctella (Hübner) (Lepidoptera: Pyralidae). Int. J. Insect Morphol. & Embryol. 9: 251-3.

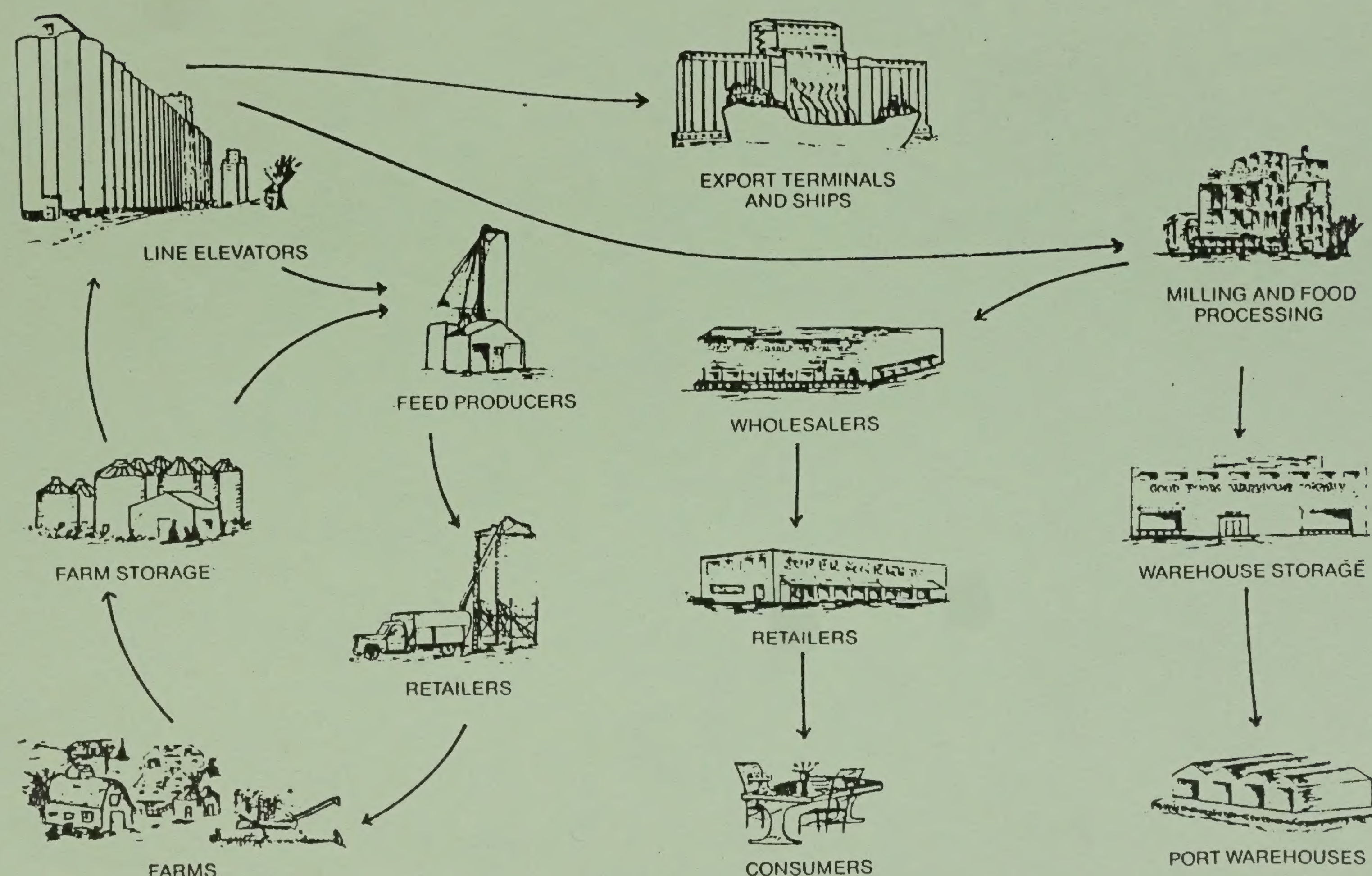
Mullen, M. A., Alfred Jones, R. T. Arbogast, J. M. Schalk, D. R. Paterson, T. E. Boswell, and D. R. Earhart. 1980. Field selection of sweet potato lines and cultivars for resistance to the sweetpotato weevil. J. Econ. Entomol. 73(2): 288-90.

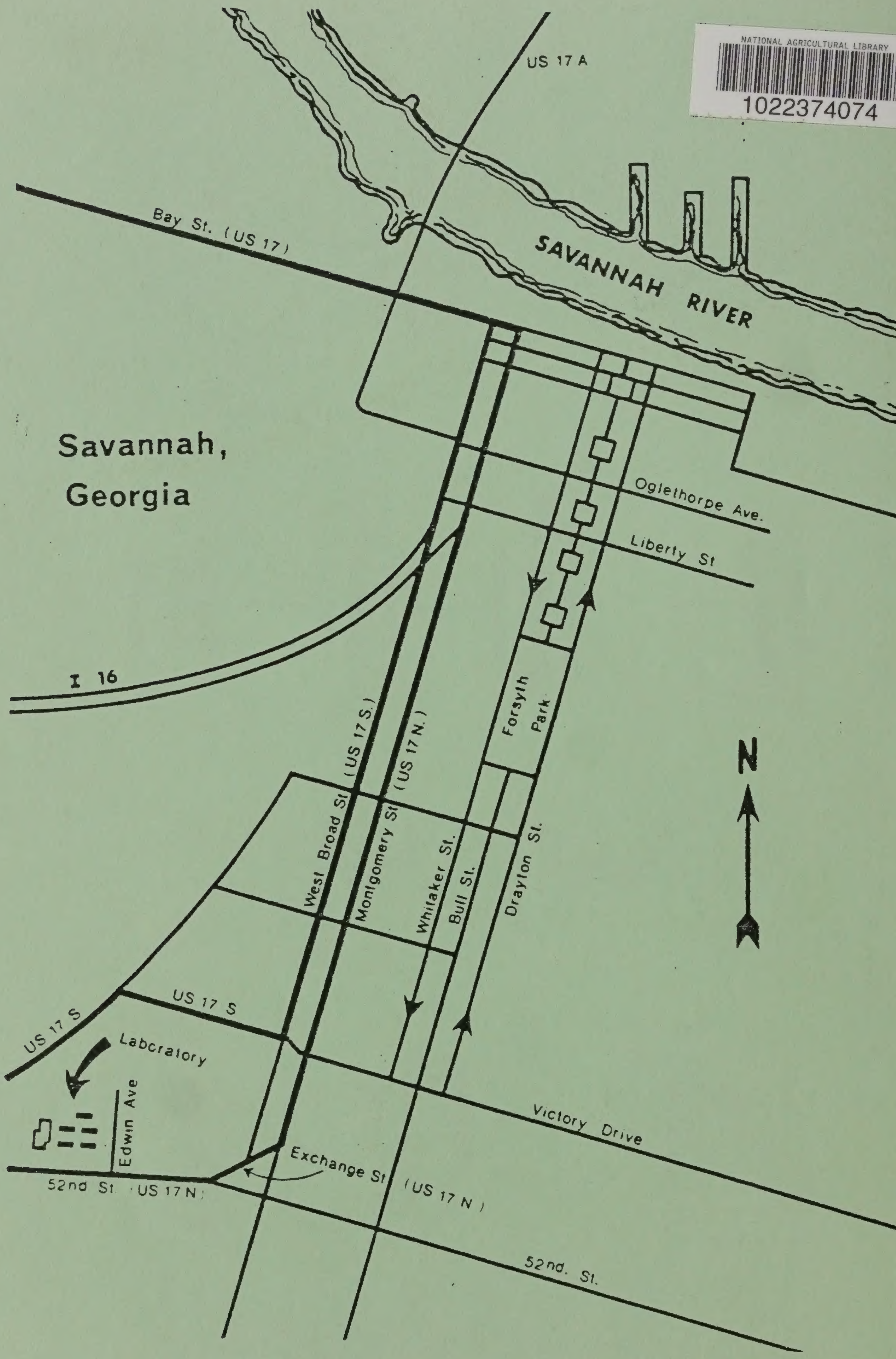
Mullen, M. A., Alfred Jones, Robert Davis, and Gordon C. Pearman. 1980. Rapid selection of sweet potato lines resistant to the sweetpotato weevil. HortScience 15(1): 70-1.

Su, Helen C. F., and B. L. Sondengam. 1980. Laboratory evaluation of toxicity of two alkaloidal amides of Piper guineense to four species of stored-product insects. J. Ga. Entomol. Soc. 15(1): 47-52.

Zehner, James M., Richard A. Simonaitis, and Roy E. Bry. 1980. High performance liquid chromatographic determination of bendiocarb on wool. J. Assoc. Off. Anal. Chem. 63(1): 47-8.

A TYPICAL MARKETING CHANNEL FOR GRAINS OR OILSEEDS




Savannah,
Georgia
SAVANNAH RIVER
US 17 A
Bay St. (US 17)
Oglethorpe Ave.
Liberty St
I 16
Forsyth Park
West Broad St (US 17 S.)
Montgomery St (US 17 N.)
Whitaker St.
Bull St.
Drayton St.
N
US 17 S
US 17 S
Laboratory
Edwin Ave
Victory Drive
Exchange St (US 17 N)
52nd St US 17 N
52nd. St.